# Distributed Generation

*Providing Reliable, Flexible Power*

# INTRODUCTION

## A NEW VIEW ON ENERGY USE

A confluence of utility restructuring, technology evolution, public environmental policy, and an expanding electricity market are providing the impetus for distributed generation to become an important energy option in the new millennium.

Distributed generation strategically applies relatively small generating units (typically less than 30 MWe) at or near consumer sites to meet specific customer needs, to support economic operation of the existing power distribution grid, or both. Reliability of service and power quality are enhanced by proximity to the customer; and efficiency is improved in on-site applications by using the heat from power generation.

While central power systems remain critical to the Nation's energy supply, their flexibility to adjust to changing energy needs is limited. Because central power is composed of large, capital-intensive plants and a transmission and distribution (T&D) grid to disperse electricity, significant investments of time and money are required to increase capacity. Distributed generation, on the other hand, complements central power by: (1) providing a relatively low capital cost response to incremental increases in power demand, (2) avoiding T&D capacity upgrades by locating power where it is most needed, and (3) providing the flexibility to put surplus power back into the grid at user sites.

Utility restructuring opens energy markets, allowing the customer to choose the energy provider, method of delivery, and attendant services. The market forces favor small, modular power technologies that can be installed quickly in response to market signals. This restructuring comes at a time when:

- Demand for electricity is escalating domestically and internationally;
- Impressive gains have been made in the cost and performance of small, modular distributed generation technologies;
- Regional and global environmental concerns have placed a premium on efficiency and environmental performance; and
- Concerns have grown regarding the reliability and quality of centralized electric power generators.

Significant technological advances through decades of intensive research have yielded major improvements in the economic, operational, and environmental performance of small, modular gas-fueled power generation options. These distributed generation systems offer clean, efficient, reliable, and flexible on-site power alternatives. Fuel flexibility is also afforded by operating on natural gas, propane, or fuel gas derived from any hydrocarbon, including coal and biomass, and wastes from refineries, municipalities, and the forestry and agricultural industries.

### PROGRAM AREAS

- **Fuel Cells**
- **Gas Turbines**
- **Fuel Cell/Turbine Hybrids**
- **Advanced Gas Reciprocating Engines**

Technologies such as gas turbines and reciprocating engines are already making a contribution , but they have more to offer through focused development efforts. Fuel cells are beginning to enter the market, but will require additional research and development to realize widespread deployment. Also, fuel cell/turbine hybrid systems and 21st century fuel cells, currently in the embryonic stage, offer even greater potential.

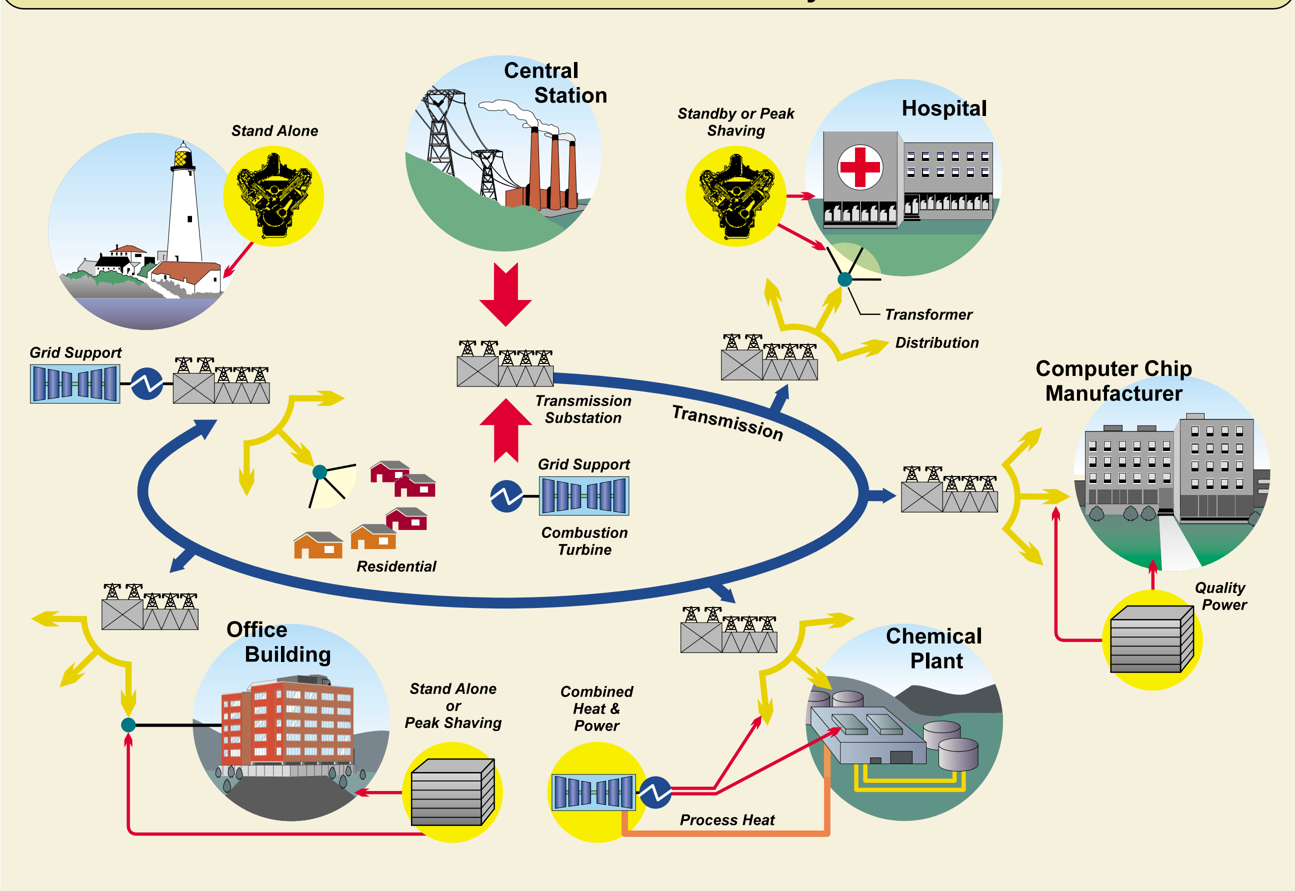
While addressing distributed generation potential in general, the program presented here focuses on stationary energy gas-based distributed generation technologies and the Department of Energy's efforts to bring them into the marketplace.

## Applications

There are a number of basic applications, outlined below, that represent typical patterns of services and benefits derived from distributed generation.

- **Standby Power.** Standby power is used for customers that cannot tolerate interruption of service for either public health and safety reasons, or where outage costs are unacceptably high. Since most outages occur as a result of storm or accident related T&D system breakdown, on-site standby generators are installed at locations such as hospitals, water pumping stations, and electronic-dependent manufacturing facilities.
- **Combined Heat and Power.** Power generation technologies create a large amount of heat in converting fuel to electricity. If located at or near a customer's site, heat from the power generator can be used by the customer in what are called combined heat and power (CHP) or cogeneration applications. CHP significantly increases system efficiency when applied to mid- to high-thermal use customers such as process industries, large office buildings, and hospitals.
- **Peak Shaving.** Power costs fluctuate hour by hour depending upon demand and generation availability. These hourly variations are converted into seasonal and daily time-of-use rate categories such as on-peak, off-peak, or shoulder rates. Customer use of distributed generation during relatively high-cost on-peak periods is called peak shaving. Peak shaving benefits the energy supplier as well, when energy costs approach energy prices.
- **Grid Support.** The power grid is an integrated network of generation, high voltage transmission, substations, and local distribution. Strategic placement of distributed generation can provide system benefits and precludes the need for expensive upgrades.

**Distributed Generation Systems**



# BENEFITS

## CUSTOMER BENEFITS

- Ensures reliability of energy supply, increasingly critical to business and industry in general, and essential to some where interruption of service is unacceptable economically or where health and safety are impacted;
- Provides the right energy solution at the right location;
- Provides the power quality needed in many industrial applications dependent upon sensitive electronic instrumentation and controls;
- Offers efficiency gains for on-site applications by avoiding line losses and using both electricity and the heat produced in power generation for processes or heating and air conditioning;
- Enables savings on electricity rates by self-generating during high-cost peak power periods, and adopting relatively low-cost interruptible power rates;
- Provides a stand-alone power option for areas where transmission and distribution infrastructure does not exist or is too expensive to build;
- Allows power to be delivered in environmentally sensitive and pristine areas by having characteristically high efficiency and near-zero pollutant emissions;
- Affords customers a choice in satisfying their particular energy needs; and
- Provides siting flexibility by virtue of the small size, superior environmental performance, and fuel flexibility.

## SUPPLIER BENEFITS

- Limits capital exposure and risk because of the size, siting flexibility, and rapid installation time afforded by the small, modularly constructed, environmentally friendly, and fuel flexible systems;
- Avoids unnecessary capital expenditure by closely matching capacity increases to growth in demand;
- Avoids major investments in transmission and distribution system upgrades by siting new generation near the customer;
- Offers a relatively low-cost entry point into a competitive market; and
- Opens markets in remote areas without transmission and distribution systems, and in areas without power due to environmental concerns.

## NATIONAL BENEFITS

- Reduces greenhouse gas emissions through efficiency gains and potential renewable resource use;
- Responds to increasing energy demands and pollutant emission concerns while providing low-cost, reliable energy essential to maintaining competitiveness in the world market;
- Positions the United States to export distributed generation technologies in a rapidly growing world energy market, the largest portion of which is devoid of a transmission and distribution grid;
- Establishes a new industry worth billions of dollars in sales and hundreds of thousands of jobs; and
- Enhances productivity through improved reliability and quality of power delivered, valued at billions of dollars per year.

# THE OPPORTUNITY

The importance of distributed generation is reflected in the size of the estimated market. Domestically, new demand combined with plant retirements is projected to require as much as 1.7 trillion kilowatt-hours of additional electric power by 2020, almost twice the growth of the last 20 years. Over the next decade, the domestic distributed generation market, in terms of installed capacity to meet the demand, is estimated to be 5–6 gigawatts per year.

Worldwide forecasts show electricity consumption increasing from 12 trillion kilowatt hours in 1996 to 22 trillion kilowatt hours in 2020, largely due to growth in developing countries that lack nationwide power grids. The projected distributed generation capacity increase associated with the global market is conservatively estimated at 20 gigawatts per year over the next decade.

The projected surge in the distributed generation market is attributable to a number of factors. Under utility restructuring, energy suppliers, not the customer, must shoulder the financial risk of the capital investments associated with capacity additions. This favors less capital-intensive projects and shorter construction schedules.

Also, while opening up the energy market, utility restructuring places pressure on reserve margins as energy suppliers increase capacity factors on existing plants to meet growing demand rather than install new capacity. This squeezing of the margins increases the probability of forced outages. As a result, customer concerns over reliability have escalated, particularly those in the manufacturing industry.

With the increased use of sensitive electronic components, the need for reliable, high-quality power supplies is paramount for most industries. The cost of power outages, or poor quality power, can be economically devastating to industries with continuous processing and pinpoint-quality specifications. Studies indicate that nationwide, power fluctuations cause annual losses of $12–26 billion.

As the power market opens up, the pressure for enhanced environmental performance increases. In many regions in the U.S. there is near-zero tolerance for additional pollutant emissions as the regions strive to bring existing capacity into compliance. Public policy, reflecting concerns over global climate change, is providing incentives for capacity additions that offer high efficiency and use of renewables.

Overseas, the utility sector is undergoing change as well, with market forces displacing government controls, and public pressure forcing more stringent environmental standards. Electricity demand worldwide is forecasted to nearly double. Moreover, there is an increasing effort to bring commercial power to an estimated 2 billion people in rural areas that currently do not have access to a power grid.

Robotic fabrication, as shown here, is becoming commonplace in the manufacturing industry and is mandating high-quality power for the associated electronic components.

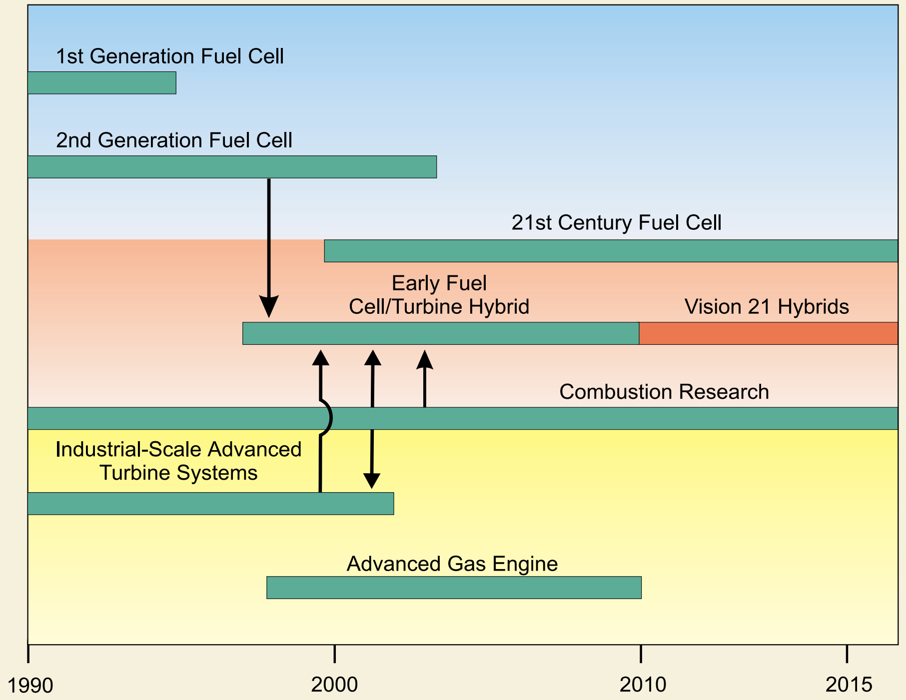
## The Program

The C&PS Distributed Generation Program involves: (1) research, development, and demonstration to optimize the cost and performance, and to accelerate the readiness of a portfolio of advance gas-fueled distributed generation systems for both domestic and foreign markets; and (2) policy development necessary to remove barriers to widespread distributed generation deployment. The Program is being carried out in partnership with other federal agencies, state governments, technology suppliers, industry research organizations, academia, power generators, energy service companies, and end users.

A cooperative government/ industry effort has resulted in successful commercialization of a first generation of fuel cells using a phosphoric acid electrolyte. Turnkey 200-kW phosphoric acid fuel cell (PAFC) plants have been installed at more than 165 sites around the world. PAFC systems operate at about 200°C (400°F) with electrical efficiencies ranging from 40–45 percent on a lower heating value basis (LHV).

Second-generation fuel cells are under development that provide both higher fuel-to-electricity efficiencies and temperatures. The technologies include the molten carbonate fuel cell (MCFC) and the solid oxide fuel cell (SOFC). The high temperatures (650°C for MCFCs and 1,000°C for SOFCs) enable internal reforming of fuels and provide high-quality heat for CHP and combined-cycle applications. The heat developed in producing electricity also makes MCFCs and SOFCs ideal candidates for integration with gas turbines. Both have the potential to reach fuel-to-electricity efficiencies of 50 to 60 percent LHV.

**Roadmap**

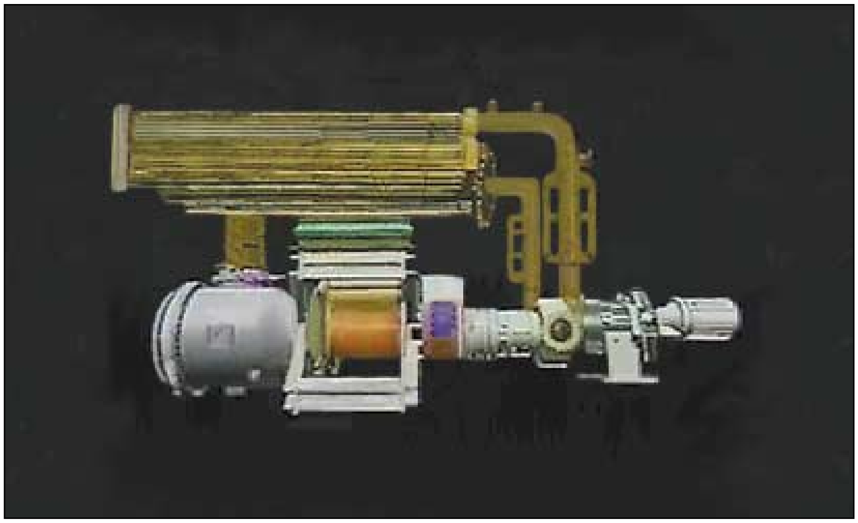


These second-generation systems are currently being demonstrated, with market entry for natural gas-based systems planned for 2003. Demonstration objectives include reducing capital costs to $1,500/kW. Subsequent to market entry, capital costs are expected to decline as manufacturing capacity and capability increase. Follow-on testing will address expanding the fuel options by testing other reformed fuels and associated cleanup systems.

Parallel research and development into new ceramic materials and manufacturing techniques is ongoing. It explores means to enhance performance and lower costs in support of both the MCFC and SOFC development as well as future 21st century fuel cells that can be manufactured at far lower cost and reach efficiencies of 80 percent LHV. These potentially very low-cost fuel cells promise deeper and wider market penetration.

Another an important element of the Distributed Generation Program is the Department of Energy's Advanced Turbine Systems (ATS) Program. The Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy (EERE) Office of Industrial Technologies share responsibility for implementing the Program with industrial partners. The Program encompasses simple-cycle industrial gas turbines for distributed generation applications and utility-scale gas turbine combined-cycle systems for central station markets.

In the near term, industrial gas turbines with efficiencies of 40–43 percent will be available as a result of two industrial-scale ATS Projects. As to future activities, these ATS designs will become platforms for fuel flexible turbine/fuel cell hybrids of increasingly better performance, as high-temperature materials are proven.



The Solar Mercury™ 50 Turbine System

Efforts have also begun to develop a system that integrates a fuel cell with a gas turbine. Hybrid fuel cell/gas turbine technology for stationary power generation offers the potential to achieve efficiencies in excess of 80 percent, nitrogen oxides and carbon monoxide emissions less than 2 parts per million (ppm), and costs 25 percent below a comparably sized fuel cell.

Five teams of fuel cell and turbine manufacturers are currently conducting conceptual feasibility studies on fuel cell/turbine hybrids. The goal is to develop hybrid systems with efficiencies greater than 70 percent for market entry by 2010. More advanced Vison 21 hybrids configured with 21st century fuel cells could offer 80 percent efficiency by 2015.

Combustion research supports both the fuel cell/turbine hybrid and ATS efforts by developing effective means to combust low-Btu gases and to achieve low emissions in high-temperature combustion. The work includes expanding the fuel range to gasification derived fuel gases (syngas).

A joint FE/EERE workshop at NETL began an initiative to enhance the efficiency and environmental performance of natural gas-fired reciprocating engines. A set of performance goals was established for increasing efficiency by 15 to 20 percent by 2010.

## Drivers

- Utility restructuring is underway, exacerbating concerns over reliability and quality of electric power.
- Electric power producers will seek energy ventures that are less capital-intensive, offer flexibility in siting, closely couple generation capacity to load growth, increase efficiency, and reduce environmental intrusion.
- High-quality and reliable power supplies are critical to many industries employing highly sensitive electric components. Studies indicate that, nationwide, power fluctuation causes annual losses of $12-26 billion.
- Electric utilities will seek to reduce capital expenditures associated with installing and/or upgrading peaking generation capacity and transmission and distribution system expansion.
- Civil, military, and special requirements for electric power need to be met in environmentally sensitive and pristine areas where transmission and distribution systems are nonexistent and only zero pollutant emissions will be tolerated.
- Rapid growth is expected in the export market to bring electricity to an estimated two billion people in rural areas currently without access to a power grid.
- Fuel flexibility in power generation will provide the consumer with options to maintain low-cost electricity, even under the pressures of increased power demand and environmental concerns.
- Regional and global environmental objectives will continue to place a premium on efficiency and environmental performance.

## Goals

- Commercially introduce high-temperature natural gas-fueled molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) capable of 50 to 60 percent efficiency in the multi-kilowatt range at $1,000–1,500/kW. (2003)
- Expand MCFC and SOFC fuel use to gasified coal and other hydrocarbons. (2010)
- Achieve market entry for a 21st century fuel cell using solid state composition and advanced fabrication techniques to achieve 80 percent efficiency and reduce capital costs to $400/kW with stack costs of $100/kW. (2015)
- Commercially introduce early fuel cell/gas turbine hybrids capable of 70 percent efficiency. (2010)
- Commercially introduce an advanced natural gas-fired reciprocating engine with 50 percent efficiency and 5 ppm or less $NO_x$ emissions. (2010)

## Strategies

- Work in partnership with other federal agencies, state governments, technology suppliers, industry research organizations, academia, power generators, energy service companies, and end users.
- Complete the commercial-scale demonstrations on the MCFC and SOFC systems, and use subsequent commercial sales to build manufacturing capacity to produce larger units at reduced cost.
- Integrate gas cleanup systems to enable MCFC and SOFC operation on syngas derived from gasification of coal and biomass, and municipal, forestry, and refinery wastes.
- Use technology-based research into materials and manufacturing techniques to initiate development of a new solid state fuel cell system that significantly reduces fabrication cost and realizes quantum jumps in efficiency.
- Develop an early market entry fuel cell/gas turbine hybrid by integrating MCFC and SOFC fuel cells with industrial-scale ATS designs using teams comprised of the fuel cell and turbine developers.
- Use the technology base research in low-Btu combustion, materials, and manufacturing from both the fuel cell and turbine programs to enhance fuel cell/gas turbine hybrid system performance and expand fuel flexibility.
- Use U.S.-based engine and components manufacturers consortium and universities to develop a natural gas-fired reciprocating engine superior to any in the world.

## Measures of Success

- Achieve early market entry for MCFC and SOFC fuel cells (2003), expand sales, and establish a strong U.S.-based manufacturing capability to competitively produce MCFC and SOFC fuel cells up to 100 MW capacity. (2010)
- Have the gasification and gas cleanup systems in place to expand fuel cell fuels to coal and biomass, and municipal, forestry, and refinery wastes. (2010)
- Establish the capability to manufacture solid state fuel cells at less than one-half the cost of today's MCFC and SOFC fuel cells. (2015)
- Establish a strong U.S. technology leadership position in fuel cell/gas turbine hybrids. (2010)
- Establish a strong U.S. technology leadership position in gas-fired reciprocating engines. (2010)

## Program Areas

The following is a discussion of the Program Areas that comprise the OC&PS Distributed Generation Program. The program focuses on stationary energy gas-based distributed generation technologies. OC&PS and the Office of Energy Efficiency and Renewable Energy (EERE) share responsibility for the ATS Program component. Moreover, EERE has responsibility for developing non-gas-based distributed generation technologies such as photovoltaics, solar-thermal, wind, and modular biomass systems.

Distributed generation complements central power by:
(1) providing a relatively low capital cost response to incremental increases in power demand,
(2) avoiding T&D capacity upgrades by locating power where it is most needed, (3) having the flexibility to put power back into the grid at user sites, and
(4) providing technologies that can be integrated with central power energy platforms to enhance performance.

## Fuel Cells

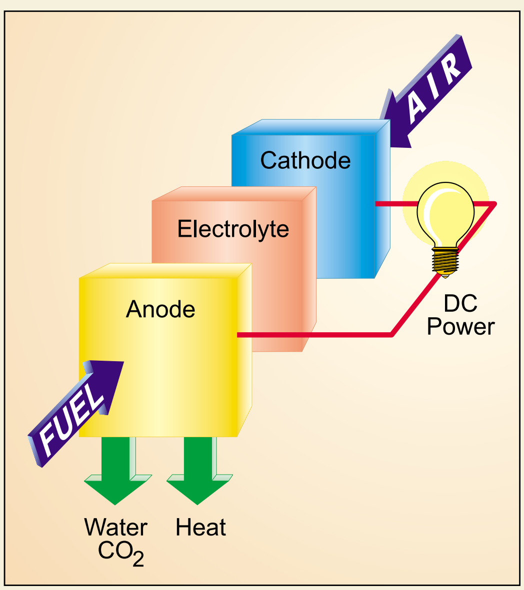
### Performance Targets

**2nd Generation**
Efficiency: 50-60% LHV
Cost: $1,000–1,500/kW
Year: 2003

**21st Century**
Efficiency: 70-80% LHV
Cost: $400/kW
Year: 2015

Fuel cells work without combustion and its environmental side effects. Power is produced electrochemically by passing a hydrogen-rich fuel over an anode and air over a cathode and separating the two by an electrolyte. In producing electricity, the only by-products are heat, water, and $CO_2$. Hydrogen fuel can come from a variety of hydrocarbon resources by subjecting them to steam under pressure (called reforming or gasification).

**Fuel Cell**




The electrolyte, which induces the fuel cells electrochemical reactions, can be composed of liquid or solid media. The media used differentiates the type of fuel cell.

The direct electrochemical reaction in lieu of moving parts to produce electricity, has inherent efficiency advantages. Efficiency can be enhanced by using the high energy heat derived from the fuel cell reactions either in combined heat and power (CHP) or combined-cycle applications (generating steam for additional electric power). The $CO_2$ is in concentrated form, which facilitates capture for recycling or sequestration. The absence of moving parts results in very low noise levels. The stacking of cells to obtain a usable voltage and power output allows fuel cells to be built to match specific power needs, and the modularity makes capital cost relatively insensitive to scale.

While PAFCs operate at about 200°C (400°F) and 40–45 percent fuel-to-electricity efficiencies on a lower heating value basis (LHV), higher temperature second-generation fuel cells achieve higher fuel-to-electricity and thermal efficiencies. The higher temperatures contribute to improved fuel-to-electricity efficiencies and enable generation of steam for cogeneration, combined-cycle applications, and reforming of fuels.

One of two high-temperature fuel cells currently under development is the molten carbonate fuel cell (MCFC). MCFC technology has the potential to reach fuel-to-electricity efficiencies of 50 to 60 percent LHV. Operating temperatures for MCFCs are around 650°C (1,200°F), which allows total system thermal efficiencies up to 85

100-kW SOFC cogeneration system operating in the Netherlands, built by Siemens-Westinghouse


Fuel Cell Energy's first commercial prototype 250-kW MCFC full-size stack demonstration unit

percent LHV in combined-cycle applications.

The other high-temperature fuel cell under development is the solid oxide fuel cell (SOFC). SOFCs operate at temperatures up to 1,000°C (1,800°F), which further enhances combined-cycle performance. The solid-state ceramic construction enables the high temperatures, allows more flexibility in fuel choice, and contributes to stability and reliability. As with MCFCs, SOFCs are capable of fuel-to-electricity efficiencies of 50 to 60 percent LHV and total system thermal efficiencies up to 85 percent LHV in combined-cycle applications.

Second-generation fuel cell development is proceeding efficiently. NETL is working with Fuel Cell Energy and M-C Power to bring two versions of the MCFC to commercial fruition, and is working with Siemens-Westinghouse Power Corporation to commercialize the SOFC.

By 2003, natural gas-fueled MCFCs and SOFCs will be commercially available in sizes up to 2MW. As market acceptance and manufacturing capacity increases, natural gas-fueled plants in the 50- to 100-MW range will become available. Follow-on testing will address expanding the fuel options by testing other reformed fuels and associated cleanup systems. By 2010, a transition to coal-gas-powered fuel cells will occur as gasification and gas cleanup costs are reduced through commercial plant replications.

A set of cost and performance targets have been established for a 21st Century Fuel Cell that will provide wider and deeper penetration into a full range of market applications. These targets include achieving stack fabrication and assembly costs of $100/kW, system costs of $400/kW, efficiencies of 70-80 percent, near-zero emissions, and compatibility with carbon sequestration. Long-term materials development, integration of design, high-speed manufacturing, and materials selection from the start are deemed critical to meeting the goals. These targets represent order-of-magnitude improvements in power density and cost and a doubling improvement in efficiency.

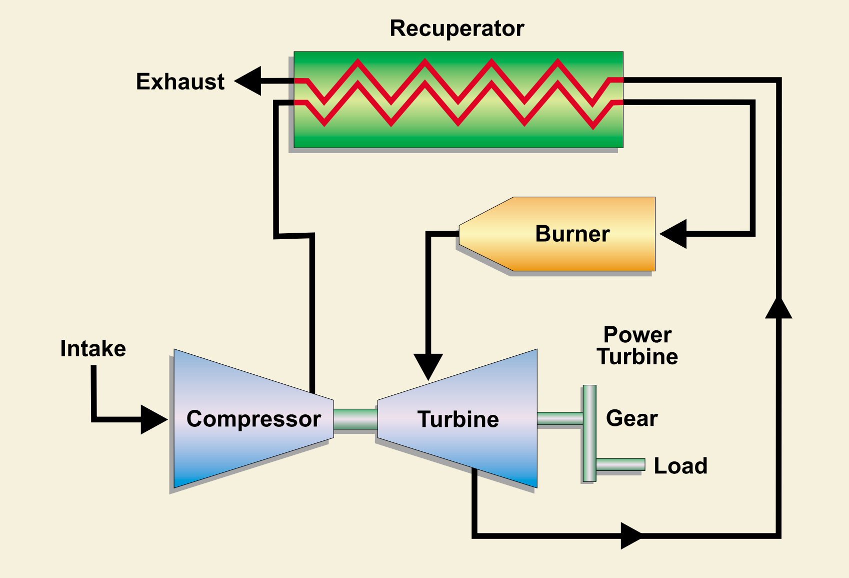
## Gas Turbines

A gas turbine produces a high-temperature, high-pressure gas working fluid, through combustion, to induce shaft rotation by impingement of the gas upon a series of specially designed blades. The shaft rotation drives an electric generator and a compressor for the air used by the gas turbine. Many turbines also use a heat exchanger called a recuperator to impart turbine exhaust heat into the combustor's air/fuel mixture. As for capacity, recently emerging microturbines, evolved from automotive turbochargers, are about to enter the market with outputs as low as 25 kW. Next generation utility-scale turbines are rated at nearly 400 MW in combined-cycle applications.

Gas turbines produce high quality heat that can be used to generate steam for CHP and combined-cycle applications, significantly enhancing efficiency. They accommodate a variety of gases including those derived from gasification of coal, biomass, and hydrocarbon wastes. However, pollutant emissions, primarily nitrogen oxides, are a concern particularly as turbine inlet temperatures are increased to improve efficiency.

Currently, industrial-scale simple cycle machines have efficiencies around 30 percent. The industrial-scale portion of the ATS Program, addressed here, seeks to improve on that efficiency by 15 percent. Additional objectives are 10 percent reduction in the cost of electricity, enhanced fuel flexibility, less than 10 ppm nitrogen oxides and 25 ppm carbon monoxide without post-combustion controls, and reliability-availability-maintainability-durability equal to or better than current systems.

**Typical Gas Turbine**




In the near term, gas turbines with efficiencies of 40 to 43 percent will be available as a result of the ATS efforts. Under the ATS Program, the Allison Engine Company took the approach of increasing inlet temperature to 2,400 ºF, increasing the pressure ratio to 30:1, and using staged lean premix fuel injection and catalytic combustion. Plans are to introduce these features in an existing product line. Solar Turbines, Inc. is using a modest inlet temperature of 2,200 ºF and pressure ratio of 9:1, and is incorporating a high efficiency recuperator. These features are to be incorporated in the 4.2-MWe Solar Mercury™ 50 and introduced into the market in 2000.

The ATS Program includes two supporting activities. One addresses critical materials and manufacturing issues, with the objective of hastening the incorporation of new materials and components in gas turbines. Work includes development of thermal barrier coatings and advanced casting techniques for single crystal turbine components, and is being carried out by industry with assistance from national laboratories and universities. The other supporting activity, the Advanced Gas Turbine Systems Research (AGTSR) Program, is an effort to establish a scientific foundation for a next-century gas turbine. The South Carolina Institute for Energy Studies is coordinating the AGSTR Program, a consortium of more than 97 universities in 37 states formed to advance the fundamental knowledge base in gas turbines requisite to continued improvement.

As for future activities, the advanced turbine systems will become the platforms for the fuel cell/turbine hybrids. And the advanced high-temperature materials and supporting processes emerging from successful research will be integrated over time into ATS components and subsystems to enhance efficiency and performance.

## Fuel Cell/Turbine Hybrids

### Performance Targets

**Efficiency (LHV):**
70% by 2010
80% by 2015

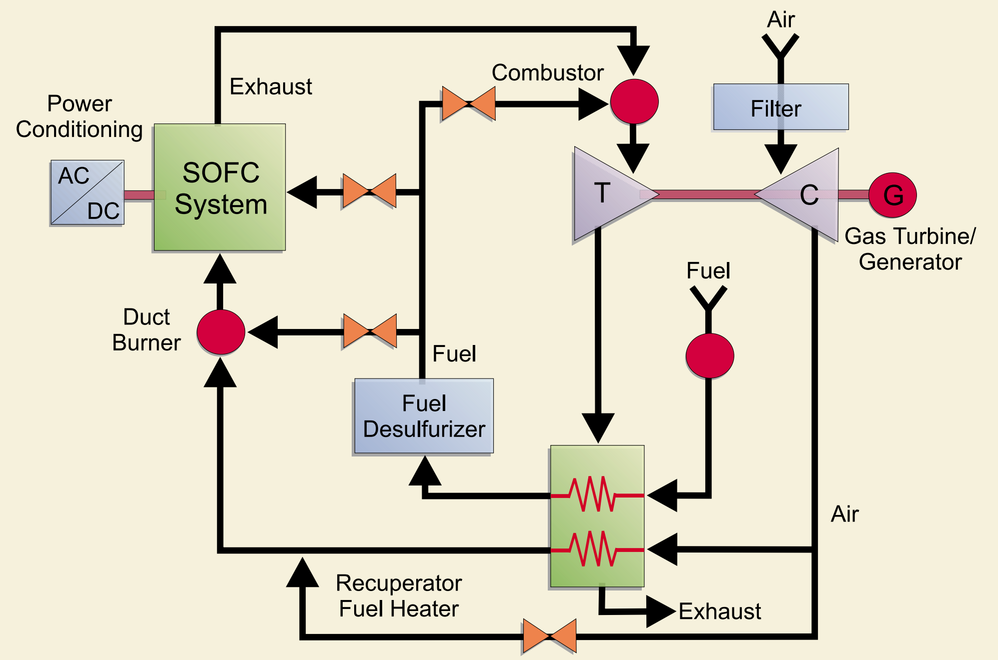
System studies to date indicate that fuel cell/turbine hybrids could realize a 25 percent increase in efficiency and 25 percent reduction in cost for a comparably sized fuel cell. The synergy realized by fuel cell/turbine hybrids derives primarily from using the rejected thermal energy and combustion of residual fuel from a fuel cell in driving the gas turbine. This leveraging of the thermal energy makes the high-temperature MCFCs and SOFCs ideal candidates for hybrid systems. Use of a recuperator contributes to thermal efficiency by transferring heat from the gas turbine exhaust to the fuel and air used in the system.

Exploratory research on fuel cell/turbine hybrids is underway in partnership with the National Fuel Cell Research Center at the University of California at Irvine and at NETL. The experimental work involves evaluation of a 75-kW turbine operating in combination with a simulated fuel cell. The particular focus is on dynamic operating conditions (startup, shutdown, load following, and upsets) and the associated controls. The objective is to establish: (1) key operating parameters and their interrelationships, (2) a range of safe operating conditions, and (3) a database and dynamic modeling tools to support further development.

Also supporting hybrid system development is a fully instrumented NETL Low-Btu Combustion Studies Facility. Fuel cell anode gases can be simulated for combustor design studies.

In an attempt to develop an early-entry hybrid system, five teams of fuel cell and turbine manufacturers have been engaged to conduct conceptual feasibility studies on fuel cell/turbine systems. The teams are predominately composed of the high-temperature MCFC and SOFC fuel cell manufacturers and the turbine manufacturers participating in the DOE's ATS program. The goal is to develop hybrid systems with efficiencies greater than 70 percent for market entry by 2010. As hybrid system capability increases, efficiencies of 80 percent are expected by 2015 along with designs for integration into Vision 21 Plants.

**Example of Fuel Cell/Turbine Hybrid System**




Courtesy of Siemens-Westinghouse

## Advanced Gas Engines

### Performance Targets

**Size:** <5 MW

**Efficiency:** 50% LHV

**$NO_x$ Emissions:** <5 ppm

**Year:** 2010

Reciprocating engines, or piston-driven internal combustion engines, are a widespread and well-known technology. These engines offer low capital cost, easy startup, proven reliability, good load-following characteristics, and heat recovery potential. Incorporation of exhaust catalysts and better combustion design and control significantly reduced pollutant emissions over the past several years.

With the greatest distributed generation growth occurring in the under-5-MW market, reciprocating engines have become the fastest selling distributed generation technology in the world today. Of the reciprocating engines, spark ignition natural gas-fired units have increased their percent of market share by over 150 percent from 1995–1997. The reason for increased popularity stems from low initial installed costs, low operating costs, and low environmental impact.

Natural gas-fired reciprocating engine capacities typically range from 0.5–5 MW. The highest efficiencies achieved for these engines, which occur in the mid-range of 1–2 MW, are 38–40 percent for domestic engines and as high as 44 percent for some European engines.

A recent Advanced Stationary, Reciprocating, Natural Gas Engine Workshop concluded that a research and development initiative is warranted to enhance the cost and performance of spark ignition natural gas-fired engines in the less-than-5-MW market. Goals identified include:

Reciprocating engine at University of Alaska, Fairbanks


NETL in-house reciprocating engine research

- Increasing efficiency 15–20 percent,
- Reducing $NO_x$ emission levels,
- Reducing total hydrocarbon emission levels,
- Reducing hazardous air pollutants,
- Reducing cost of electricity, and
- Maintaining durability and reliability levels.

Participation in the workshop included a consortium of four engine manufacturers and several engine component suppliers, as well as a strong university contingent that identified potential future academic partnerships.

The impetus for continuing growth in engine use is the anticipated rapid expansion of distributed generation domestically and internationally, and the preference for reciprocating engines in the less-than-5-MW market. Domestically, realizing performance goals will alleviate potential strain on natural gas supplies and essentially eliminate pollutant emission concerns. Internationally, improved cost and performance will provide U.S. engine manufacturers a strong market position.

As with the other gas-based distributed generation systems, reciprocating engine technology is adaptable to other gases such as landfill gas and propane, and gases derived from gasification of coal, biomass, and municipal, forestry, and refinery wastes.

## PROGRAM SUCCESS

While 175 PAFC fuel cells have been manufactured for sale at various locations around the world, a recent installation in New York City's Central Park underscores several important advantages offered by fuel cells. The Department of Energy in partnership with the New York Power Authority installed a 200-kW PAFC in Central Park to provide electricity to the Police Department's 22nd precinct station. Prior to the fuel cell installation, power supply to the 148-year-old precinct station, a converted horse stable, often precluded simultaneous operation of all office equipment. This on-site fuel cell avoided an estimated \$1.2 million power line upgrade, provided an inconspicuous clean power supply about as large as a double size garden shed, and allowed recharging of non-polluting electric vehicles used by the police. The government provided about one-third of the project cost under a Department of Defense-funded program administered by the Department of Energy. The program is designed to accelerate introduction of fuel cells and develop a U.S. manufacturing capability.


PAFC units (manufactured by the ONSI Corporation) have been sited, permitted, installed, started, operated, and maintained in a real-world environment. The fleet of ONSI fuel cells continues to demonstrate reliable, safe operation in a variety of climates, applications, and service scenarios. Here, an ONSI fuel cell unit is being installed in a nearby location in Times Square in New York City.

Photo courtesy of ONSI Corporation